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### (54) Method for the preparation of melamine

(57) The invention relates to a method for the preparation of melamine from urea in which melamine is recovered from a urea pyrolysis reaction product containing melamine by combining the reaction product with a liquid medium to produce a liquid mixture. The pressure of the mixture is then increased, if necessary, following which the liquid mixture is expanded, whereupon the medium evaporates and solid melamine is obtained as a dry material. Preferably ammonia is used as the liquid medium.

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**Description****BACKGROUND OF THE INVENTION****1. Field of the Invention**

The invention relates to a method for the recovery and purification of melamine from urea in which melamine is recovered from a urea pyrolysis reaction product comprised of melamine by mixing the reaction product with a medium, pressurizing the resulting mixture, and then expanding the pressurized mixture whereupon the medium evaporates and a dry solid very high purity melamine is produced. More particularly, the invention relates to a method for the recovery and purification of melamine from urea via a non-catalytic, high-pressure process in which melamine is recovered from a melamine melt leaving the melamine reactor vessel by mixing the melamine melt with a liquid medium, in particular ammonia, pressurizing the resulting mixture, and then expanding the pressurized mixture which evaporates the liquid medium and produces dry solid high purity melamine. The product thus obtained is commercially usable.

**2. Description of the Related Art**

A continuous, anhydrous, non-catalytic, high-pressure process for the production of melamine from urea is described in U.S. Patent No. 4,565,867, the complete disclosure of which is incorporated herein by reference. The patent describes the pyrolysis of urea in a reactor at a pressure of about 10.3 MPa to 17.8 MPa and a temperature of about 354°C to 427°C to produce a reaction product which contains liquid melamine, CO<sub>2</sub> and NH<sub>3</sub> and is transferred under pressure, as a mixed stream, to a gas-liquid separator unit. In the gas-liquid separator unit, which is kept at virtually the same pressure and temperature as the reactor, the reaction product is separated into gaseous and liquid streams. The gaseous stream contains CO<sub>2</sub> and NH<sub>3</sub> off-gases and also melamine vapor while the liquid stream consists substantially of liquid melamine. The gaseous product is sent to a gas scrubber, while the liquid melamine is transferred to a product cooler. In the gas scrubber the above-mentioned CO<sub>2</sub> and NH<sub>3</sub> off-gases and melamine vapor, are scrubbed, at virtually the same pressure as the reactor pressure, with molten urea so as to pre-heat the urea, cool said off-gases and remove the melamine. The pre-heated urea, which contains the removed melamine, is then fed to the reactor. Meanwhile, in the product cooler, the pressure and temperature of the liquid melamine from the gas-liquid separator are reduced by means of a liquid cooling medium, preferably liquid ammonia, so as to produce a solid melamine product.

The drawback of this method is that the purity of the melamine obtained is typically in the range of 96 to 99.5%. Besides melamine, contaminants such as urea, CO<sub>2</sub>, ammeline-related compounds and other organic

solids (melem and melam, for example) are present. The resulting purity of such a product is not high enough for some critical melamine applications, such as coatings. There is a need for a method to directly obtain, without further purification steps, higher purity melamine.

**SUMMARY OF THE INVENTION**

10 An object of the present invention is an improved method for the preparation of very high purity melamine, generally from 99.5 to 99.95 wt.%, from urea in which the melamine is recovered from the urea pyrolysis reaction product as a dry powder. One particular object is an improved, continuous, high-pressure, non-catalytic process for the production of melamine from urea in which very high purity melamine is obtained directly as a dry powder from the melamine melt through cooling. These and other objects are achieved by the cooling of 15 a urea reaction product comprising melamine by separating the urea reaction product into gaseous and liquid phases with the liquid phase comprising melamine. The liquid phase is then transferred to a mixing vessel where it undergoes mixing with a liquid medium to produce a 20 liquid mixture at temperatures and pressures such that the formation of solid melamine is substantially avoided. Optionally, the liquid mixture is pressurized. Then the liquid mixture, further pressurized or not, is expanded 25 thereby cooling the liquid mixture, evaporating the liquid medium, and obtaining a solid very high purity melamine product. Liquid ammonia is the preferred liquid medium.

30 Another method for the preparation of very high purity melamine from urea is via a melamine melt and is accomplished by separately pressurizing both a melamine melt and a liquid medium then mixing the pressurized melamine melt and pressurized liquid medium in a mixing vessel to produce a pressurized liquid mixture. This pressurized liquid mixture is then expanded into an 35 expansion vessel whereby the liquid medium evaporates and the desired melamine product is obtained as a dry material.

**BRIEF DESCRIPTION OF THE DRAWINGS**

40 45 Figures 1 through 4 are flow diagrams of different embodiments of a system for the production of melamine from urea according to the present invention.

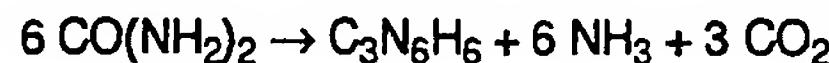
**50 DETAILED DESCRIPTION OF THE INVENTION**

55 We have now found that the purity of the melamine can be substantially increased by combining the urea pyrolysis liquid reaction product comprising melamine with a liquid medium, optionally increasing the pressure of the resulting mixture, and subsequently expanding the resulting liquid mixture, thereby evaporating the liquid medium and obtaining the melamine as a dry material. The liquid medium can be at the same, or a higher

or lower temperature than the liquid melamine, preferably lower. The resulting liquid mixture can be cooled to just above its solidification point prior to expansion. Preferably ammonia is used as the liquid medium.

More particularly we have discovered that substantial increases in the purity of the melamine can be obtained in the preparation of melamine from urea via a non-catalytic, high-pressure process, in which melamine is recovered from the liquid melamine melt leaving the reactor vessel, by combining the melamine melt with a liquid medium, optionally increasing the pressure of the resulting liquid mixture, and subsequently expanding the liquid mixture, thereby evaporating the liquid medium and obtaining melamine as a dry material. Prior to expansion, the temperature and pressure conditions of the liquid mixture are sufficient to prevent the formation of solid melamine. The liquid melamine melt leaving the reactor vessel can be combined with a liquid medium at the same or a lower or higher temperature. Preferably, the temperature of the liquid medium is lower than the liquid melamine melt. The resulting liquid mixture can be cooled to just above its solidification point prior to expansion. Preferably ammonia is used as the liquid medium. This method yields melamine having a purity, without further washing or purification, of greater than about 99 wt.%, and more specifically having a purity of about 99.5 to about 99.95 wt. %.

Urea, preferably in the form of a melt, is the preferred starting material for the production of melamine. Ammonia and carbon dioxide are by-products obtained during melamine preparation, which proceeds according to the following reaction equation:



The preparation of the melamine can be carried out at high pressure, preferably between about 5 and about 100 MPa, without a catalyst. The temperature of the reaction varies between about 325°C and about 450°C and is preferably between about 350°C and about 425°C. The ammonia and carbon dioxide by-products are generally returned to an adjoining urea plant.

The results reported herein can be obtained in a plant suited for the preparation of melamine from urea. A plant suitable for the present invention can comprise a gas scrubber, a reactor vessel, optionally in combination an internal gas-liquid separator or with a separate gas-liquid separator, one or more mixing vessels, an expansion vessel, and optionally a CO<sub>2</sub> removal unit, a post-reactor vessel or an aging vessel.

In an embodiment of the method, melamine can be prepared from urea in a plant comprising a gas scrubber, a reactor vessel which contains an internal gas/liquid separator, two mixing vessels and an expansion vessel. Urea melt is fed to the gas scrubber at a pressure of about 5 to about 100 MPa, preferably about 8 to about 20 MPa, and at a temperature above the melting point of urea. This gas scrubber can be provided with a cooling jacket so as to ensure extra cooling. The gas

scrubber can also be provided with internal cooling bodies. In the gas scrubber the liquid urea comes into contact with off-gases from the melamine reactor vessel or from a separate gas-liquid separator installed downstream of the reactor. The off-gases are composed primarily of CO<sub>2</sub> and ammonia with small amounts of melamine vapor. The urea melt scrubs the melamine vapor out of the off-gas and carries this melamine back to the reactor vessel.

In the scrubbing process the off-gases are cooled down from about the temperature of the reactor, that is from about 350°C to about 425°C, to about 175°C to 235°C, while the urea melt is heated to about 175°C to about 235°C. Below the above-mentioned minimum temperatures ammonia and carbon dioxide can condense in the bottom of the gas scrubber, which can result in the formation of ammonium carbamate, which can adversely affect the process. In order to prevent the detrimental formation of urea decomposition and/or condensation products, the gas scrubber temperature should, in general, not exceed about 275°C. The carbon dioxide and ammonia waste gases are removed from the top of the gas scrubber and are preferably returned to a urea plant for use as starting material.

The urea and melamine melt can then be withdrawn from the gas scrubber and fed, for example via a high-pressure pump, to the reactor vessel, which is at a pressure of about 5 to about 100 MPa, and preferably of about 8 to about 20 MPa. Gravity transfer of the urea melt can also be utilized by placing the gas scrubber above the reactor vessel.

In the reactor vessel the molten urea is converted into melamine, carbon dioxide and ammonia by heating to a temperature of about 325°C to about 450°C, preferably of about 350°C to about 425°C, at a pressure of about 5 to about 25 MPa, preferably of about 8 to about 20 MPa.

Ammonia can be fed to the reactor vessel in the form of a liquid or a hot vapor. The ammonia feed can serve as a purification agent to prevent clogging of the reactor vessel bottom or to prevent the formation of melamine condensation products such as melam, melem and melon, or to promote mixing in the reactor vessel. The amount of ammonia fed to the reactor is about 0 to about 10 mol per mol urea; preferably, about 0 to about 5 mol per mol urea, and in particular about 0 to about 2 mol per mol urea. The carbon dioxide and ammonia formed in the reaction as well as any extra ammonia feed into the reactor vessel can collect in an internal gas-liquid separation unit, for example in the top of the reactor vessel, or optionally in a separate gas-liquid separator downstream of the reactor vessel, and can be separated, in gaseous form, from the liquid melamine. As described above, the resulting gas mixture of carbon dioxide, ammonia and melamine is sent to the gas scrubber for removal of the melamine vapor and to preheat the urea melt. The liquid melamine is withdrawn from the reactor vessel and transferred to one or more mixing vessels.

Ammonia is added to the melamine melt in the mixing vessels and an ammonia pump is utilized to increase the pressure to about 10 to about 100 MPa, preferably about 20 to about 90 MPa and more preferably above 30 MPa. The mixing vessels are preferably equipped with means for the preparation of a melamine/ammonia mixture. The temperature in the mixing vessels can be the same as in the reactor, but can also be reduced by the ammonia, and preferably is reduced from the reactor temperature to about 1°C to about 50°C, and more preferably about 1°C to about 20°C, and more particularly about 1°C to about 10°C above the solidification point of the mixture. This cooling has the effect of converting the condensation products of melamine back into melamine and also permitting quicker solidification during the subsequent expansion, since some of the heat has already been removed. Depending on the pressure, a mixture of melamine and ammonia will contain from about 10 to about 60 wt.% dissolved ammonia, generally the amount of dissolved ammonia is greater than 10 wt.%.

Subsequently, this pressurized solution is alternately sprayed from one or the other mixing vessel into an expansion vessel. A semi-continuous flow into the expansion vessel can thus be established since the contents of one of the mixing vessels can be transferred to the expansion vessel while the other vessel is filled with melamine and pressurized with ammonia. The residence time of the mixture in a mixing vessel is between about 10 seconds and about 5 hours. Preferably, residence time is between about 1 minute and about 60 minutes.

The pressure and temperature of the expansion vessel are about 0 MPa to about 10 MPa and about 0°C to about 250°C, respectively. Preferably, the temperature is about 10°C to about 100°C. During the expansion step the evaporation of ammonia causes the temperature to drop, so that the heat of crystallization of the melamine can be discharged, yielding melamine in the form of a solid powder. Since the melamine/ammonia mixture that is being expanded is by preference a homogeneous mixture, very fast homogeneous cooling takes place, so that few by-products are formed. The evaporated ammonia is recycled and reintroduced into the process.

The melamine powder thus produced has a melamine content generally greater than about 99 wt.%, and more specifically a melamine content of about 99.5 to about 99.95 wt.% and can be employed, generally, without further purification, in applications which require very high purity melamine.

In yet another preferred embodiment of the method, instead of two mixing vessels, use is made of only one mixing vessel with a melamine pump upstream of it. The melamine pump is used, prior to the mixing vessel, to increase the pressure of the melamine to between about 10 and about 100 MPa preferably about 20 to about 90 MPa and more preferably above 30 MPa. In the mixing vessel the high pressure melamine is com-

bined with ammonia at virtually the same high pressure. This method results in a continuous flow of the homogeneous melamine/ammonia solution from the mixing vessel to the expansion vessel.

In another preferred embodiment of the method, the liquid melamine is treated in a CO<sub>2</sub> removal unit and/or a post-reactor or an aging vessel before being transferred to the expansion vessel. The aging vessel can be used in conjunction with or in place of the mixing vessel(s). In the aging vessel the liquid melamine can be contacted with about 0.01 to about 10 mol ammonia per mol melamine, and preferably about 0.1 to about 2 mol ammonia per mol melamine. The contact time in the aging vessel is between about 1 minute and about 3 hours, preferably between about 2 minutes and about 1 hour. The temperature and pressure in the aging vessel are virtually the same as in the reactor vessel. The ammonia leaving the aging vessel can subsequently be sent to the reactor vessel. In the aging vessel the melamine condensation products are converted back into melamine. The aging vessel may be positioned directly downstream of the melamine reactor vessel or between the mixing vessels and the expansion vessel. In the CO<sub>2</sub> removal unit the melamine is stripped with ammonia to remove any CO<sub>2</sub> residues. This step further increases the purity of the melamine, in particular by preventing the formation of ammeline, ammelide and cyanuric acid. The CO<sub>2</sub> removal unit is placed directly downstream of the melamine reactor vessel.

In another embodiment of the method, the melamine is synthesized at such a high pressure that after gas-liquid separation the melamine melt and the liquid ammonia can be sent directly to the expansion vessel. The pressure in the melamine reactor and the gas-liquid separator in this embodiment is between about 60 and about 100 MPa. In this embodiment, the ammonia is metered into the melamine reactor vessel to obtain the melamine/ammonia mixture which is subsequently expanded.

The flow diagram of Figure 1 illustrates an embodiment of the present invention. In this embodiment, liquid urea is fed to a gas scrubber 2 via line 1. Via line 5, a gas stream consisting of NH<sub>3</sub>, CO<sub>2</sub> and melamine is fed from gas-liquid separator 3, which is combined with synthesis zone 4, to gas scrubber 2. In this gas scrubber 2 the melamine is scrubbed from the gas stream by means of the urea stream supplied via line 1. Via line 6 the urea with the melamine enters the synthesis zone 4. A gas stream containing NH<sub>3</sub> and CO<sub>2</sub> leaves the gas scrubber 2 via line 7 to an adjoining urea plant. Via line 8 NH<sub>3</sub> can be fed to synthesis zone 4. In synthesis zone 4 the urea is heated to produce melamine, in both liquid and gaseous states, gaseous carbon dioxide, and gaseous ammonia. The gaseous and liquid phases are separated in the separator 3. The liquid melamine stream from separator 3 is alternately passed to two mixing vessels, 12 and 13, via lines 9, 10 and 11. Via line 14 NH<sub>3</sub> is supplied to pump 15 and heated and pressurized to the desired levels and then fed via lines

16 and 17 to mixing vessels 12 and 13 to produce a melamine/ammonia solution. Then, the melamine/ammonia solution is sent alternately, via lines 18 and 19, from mixing vessels 12 and 13 to expansion vessel 20, where its pressure and temperature are reduced. From this expansion vessel 20 the resulting solid very high purity melamine powder is discharged via line 21, and via line 22 the gaseous NH<sub>3</sub> is discharged to lines 8 and 14.

Figure 2 illustrates a second embodiment of the invention. In this embodiment, liquid urea is fed to a gas scrubber 2 via line 1. Via line 5, a gas stream consisting of NH<sub>3</sub>, CO<sub>2</sub> and melamine is fed from gas-liquid separator 3, which is combined with synthesis zone 4, to gas scrubber 2. In this gas scrubber 2 the melamine is scrubbed from the gas stream by means of the urea stream supplied via line 1. Via line 6 the urea with the melamine enters the synthesis zone 4. A gas stream containing NH<sub>3</sub> and CO<sub>2</sub> leaves the gas scrubber 2 via line 7 to an adjoining urea plant. Via line 8 NH<sub>3</sub> can be fed to synthesis zone 4. In synthesis zone 4 the urea is heated to produce melamine, in both liquid and gaseous states, gaseous carbon dioxide, and gaseous ammonia. The gaseous and liquid phases are separated in the separator 3. The liquid melamine stream from separator 3 is sent to a melamine pump 10 via line 9. After its pressure has been increased the liquid melamine is sent to a mixing vessel 12 via line 11. Simultaneously, via line 13 NH<sub>3</sub> is passed to pump 14. After its pressure has been increased, the NH<sub>3</sub> is passed to mixing vessel 12 via line 15 to produce a melamine/ammonia solution. Via line 16 the melamine/ammonia solution is fed to expansion vessel 17, where its pressure and temperature are reduced. Via line 18, the resulting solid very high purity melamine powder is discharged from the expansion vessel 17, and via line 19 the gaseous NH<sub>3</sub> is discharged to lines 8 and 13.

The embodiments as shown in Figures 1 and 2 and described above may also involve the use of a separate separation unit 3, as shown in Figures 3 and 4 instead of a combined reactor/separator unit. As shown in Figures 3 and 4, the gas-liquid stream from synthesis zone 4 is fed to separator 3 via lines 23 and 20 respectively. The melamine melt leaving separator 3 is treated in a similar fashion as shown in Figures 1 and 2.

Further embodiments of the present invention can also be realized using a post-reactor, an aging vessel or a CO<sub>2</sub> removal unit positioned directly downstream of the reactor/separator in line 9 or, if use is made of a post-reactor or an aging vessel, between the mixing vessel or, as the case may be, mixing vessels and the expansion vessel.

This method for the preparation of very high purity melamine has been described in patent application number 1003105 filed in The Netherlands on the date of May 14, 1996, the complete disclosure of which is hereby incorporated by reference.

The following non-limiting example further describes the present invention.

## EXAMPLE

From a melamine reactor 100 g of melamine melt was transferred to an autoclave, where it was combined with 100 g of ammonia. The pressure of the autoclave contents was raised to 80 MPa at a temperature of 250°C for 45 minutes. The mixture was then expanded to a pressure of 3 MPa. Melamine powder having a purity of 99.8 wt.% was obtained.

## Claims

1. A process for the recovery of melamine from a urea reaction product which comprises melamine, said process comprising the steps of:

separating the urea reaction product into a first gaseous phase and a liquid phase, wherein the liquid phase comprises liquid melamine;  
transferring the liquid phase to a first vessel at a temperature and a pressure to substantially avoid the formation of a second gaseous phase;  
mixing in the first vessel the liquid phase with a first portion of an ammoniacal liquid medium and thereby producing a liquid mixture at a temperature and a pressure to substantially avoid the formation of solid melamine; and  
expanding the liquid mixture into a second vessel and thereby evaporating the liquid medium and obtaining the melamine as a dry solid material.

2. A process according to claim 1, wherein the liquid medium includes ammonia.

3. A process according to claim 1, further comprising reducing the temperature of the liquid mixture in the first vessel from an initial temperature to about 1°C to about 50°C above the solidification point of the liquid mixture.

4. A process according to claim 1, wherein said mixing step is performed in at least two vessels.

5. A process for the recovery of solid melamine from a melamine melt, said process comprising the steps of:

pressurizing a melamine melt;  
pressurizing an ammoniacal liquid medium;  
mixing in a first vessel the pressurized melamine melt and the pressurized liquid medium and thereby producing a pressurized liquid mixture at a temperature and a pressure to substantially avoid the formation of solid melamine; and

expanding the pressurized liquid mixture into a second vessel and thereby depressurizing the

liquid mixture, evaporating the liquid medium and obtaining the solid melamine as a dry material.

6. A process according to claim 5, wherein said liquid medium includes ammonia. 5
7. A process according to claim 5, wherein said step of pressurizing the melamine melt involves pressurizing the melamine melt to about 10 MPa to about 10 100 MPa.
8. A process according to claim 5, wherein said step of pressurizing the liquid medium involves pressurizing the liquid medium to about 10 MPa to about 15 100 MPa.
9. A process according to claim 5, wherein said mixing step involves pressurizing the pressurized liquid mixture in the first vessel from about 10 MPa to 20 about 100 MPa.
10. A process as substantially described in the specification and the example.

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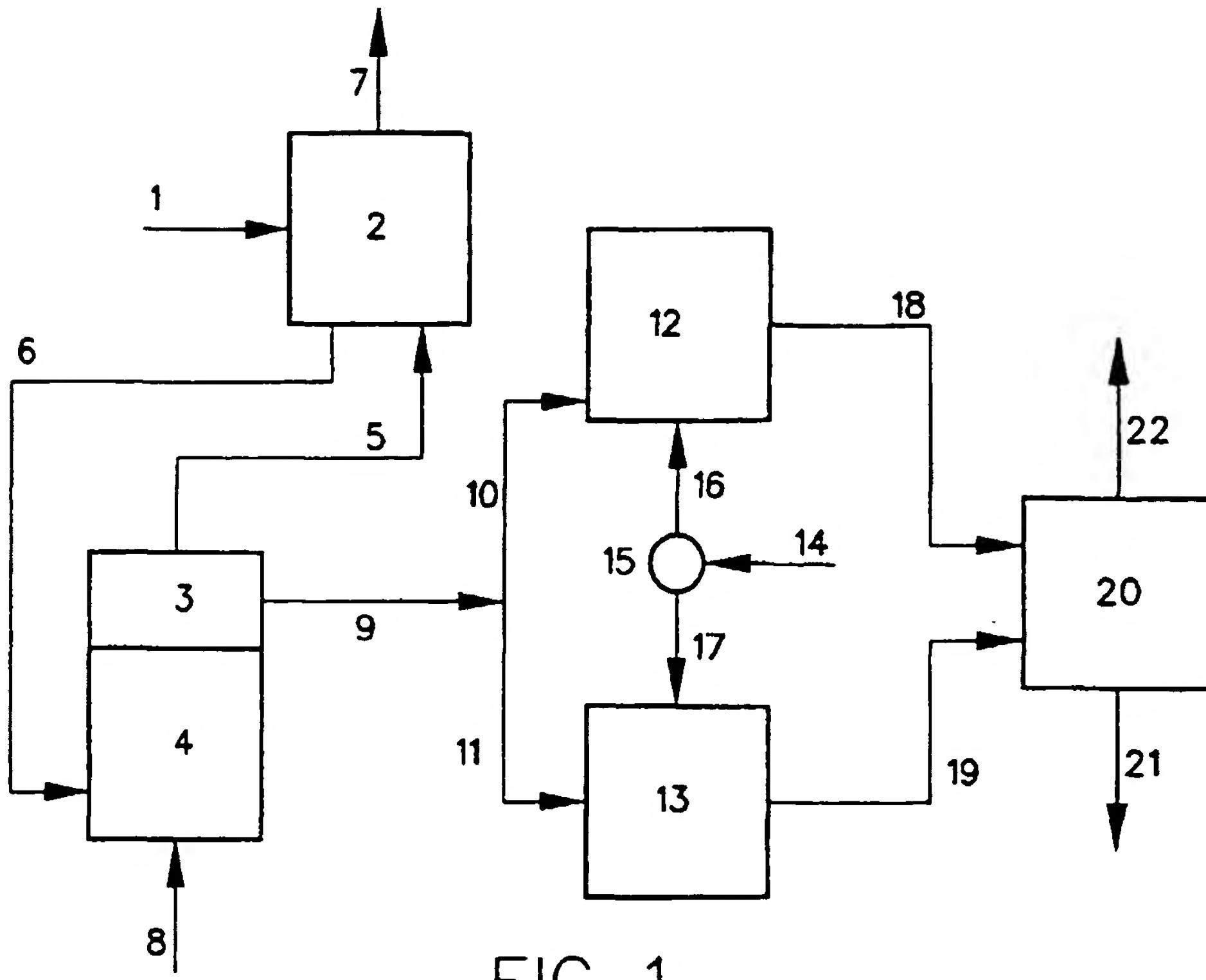


FIG. 1

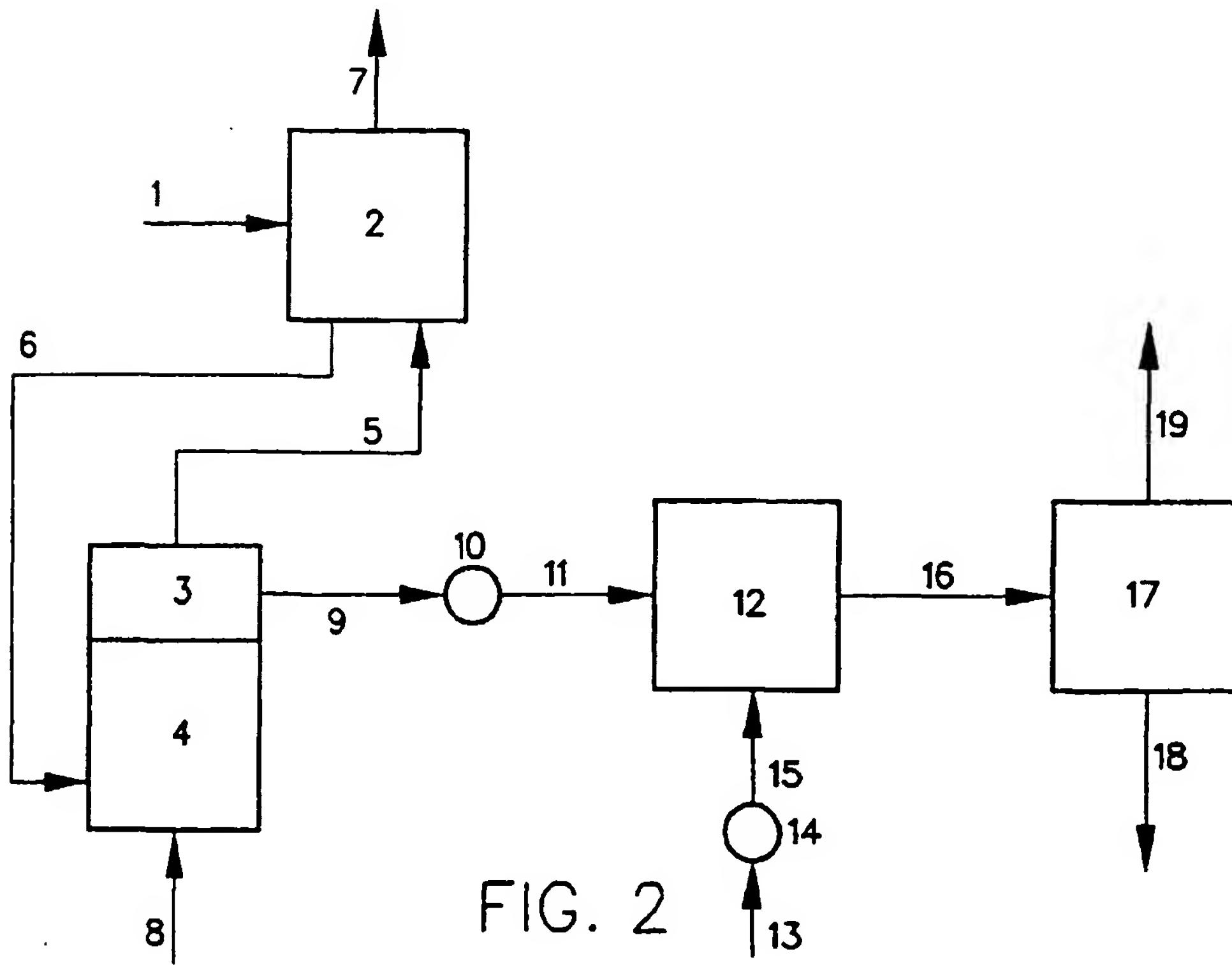


FIG. 2

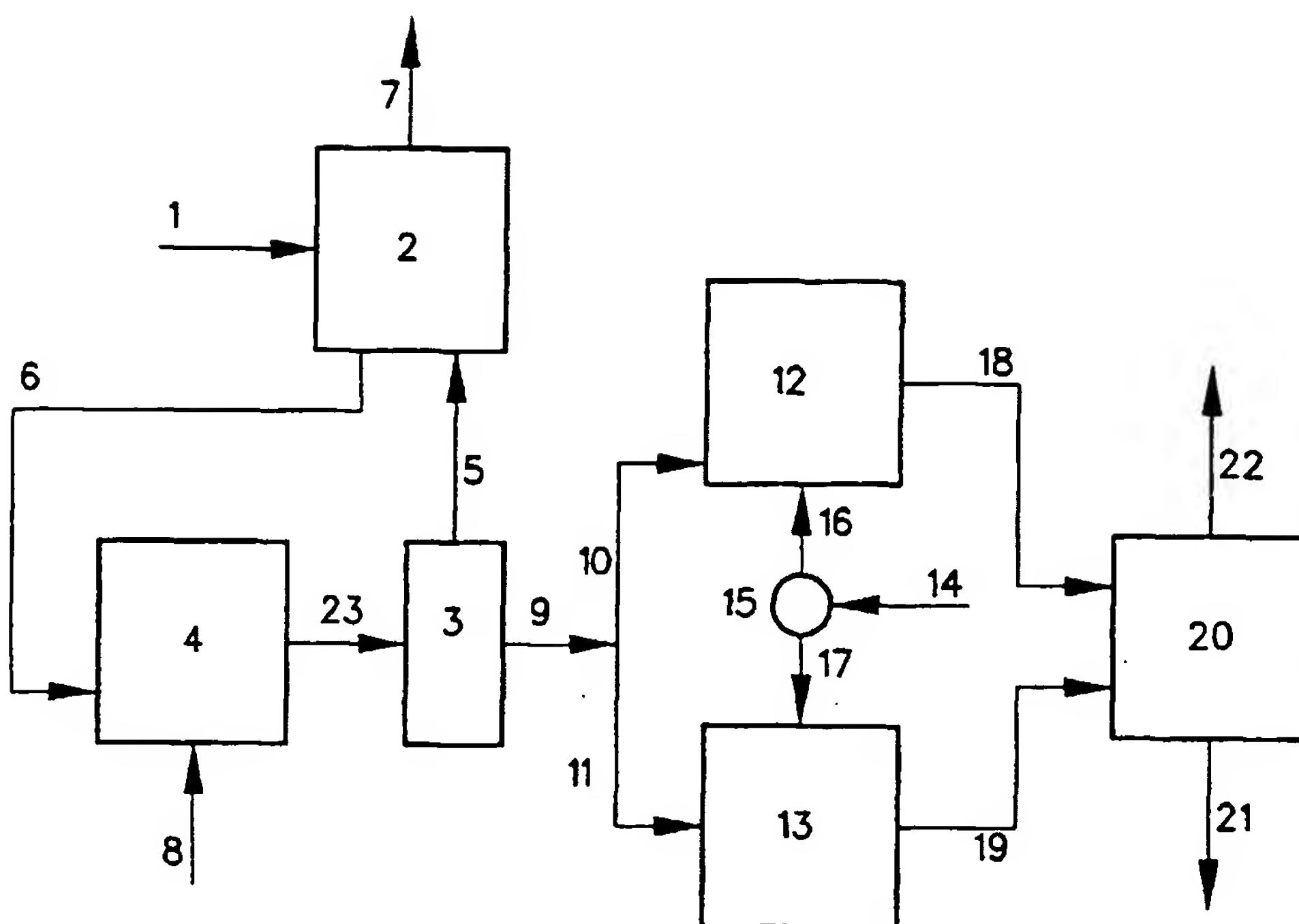


FIG. 3

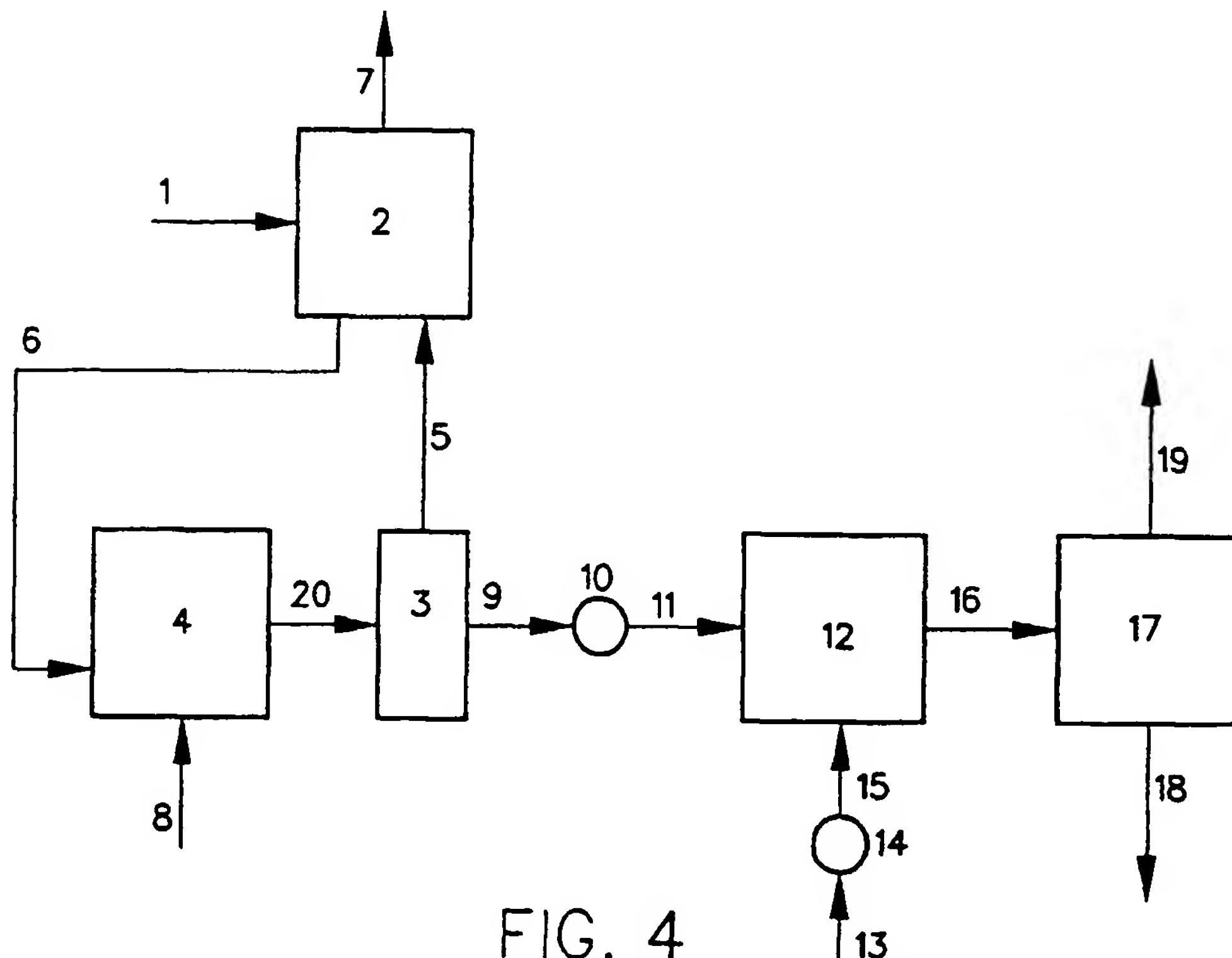


FIG. 4



## EUROPEAN SEARCH REPORT

Application Number  
EP 97 20 1380

DOCUMENTS CONSIDERED TO BE RELEVANT									
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.)						
D,A	US 4 565 867 A (MELAMINE CHEMICALS, INC.) * column 5 *	1	C07D251/60 C07D251/62						
P,X	WO 96 20182 A (AGROLINZ MELAMIN GMBH) * page 2 and 6; examples 8-10 *	1							
P,X	WO 96 23778 A (AGROLINZ MELAMIN GMBH) * complete document *	1							
P,X	EP 0 747 366 A (MELAMINE CHEMICALS, INC.) * page 4 *	1							
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TECHNICAL FIELDS SEARCHED (Int.Cl.)									
C07D									
<p>The present search report has been drawn up for all claims</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 33%;">Place of search</td> <td style="width: 33%;">Date of completion of the search</td> <td style="width: 33%;">Examiner</td> </tr> <tr> <td>THE HAGUE</td> <td>22 July 1997</td> <td>Van Bijlen, H</td> </tr> </table>				Place of search	Date of completion of the search	Examiner	THE HAGUE	22 July 1997	Van Bijlen, H
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THE HAGUE	22 July 1997	Van Bijlen, H							
<b>CATEGORY OF CITED DOCUMENTS</b> X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ..... & : member of the same patent family, corresponding document							